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TWO COMPONENT X-RAY EMISSION FROM RS CVn BINARIES

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ABSTRACT

A summary is presented of results from the Solid State Spectrometer on the Einstein Observatory for 7 RS CVn binaries. The spectra of all require two emission components, evidenced by line emission characteristic of plasma at 4-8 x 10^6K and bremsstrahlung characteristic of 20-100 x 10^6 K. We interpret the data in terms of magnetic coronal loops similar to those seen on the sun, although with different characteristic parameters. The emission regions could be defined by separate magnetic structures. For pressures less than ~ 10 dynes cm^{-2} the low temperature plasma would be confined within the stellar radii, while the high temperature plasma would, for the synchronous, close binaries, fill the binary orbits. However, for loop pressures exceeding 100 dynes cm^{-2}, the high temperature components would also be confined to within the stellar radii, in loops covering only small fractions of the stellar surfaces. While the radio properties and the occurrence of X-ray flares suggest the larger emission regions, our observations of time variations leave the ambiguity unresolved.

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I. INTRODUCTION

The first measurements of the temperatures of X-ray emission from stars indicated hotter, more luminous coronae than could be explained by acoustic heating models of the sun (Cash et al. 1978; Walter, Charles and Bowyer 1978). The 10^7 K temperature found for UX Ari excluded a gravitationally bound corona and required magnetic fields on the order of 100 gauss to bind it to one of the stellar components. Since the sun's X-ray emitting plasma is confined to magnetic loops (Vaiana and Rosner 1978), the association of magnetic fields and X-ray emission is in qualitative agreement with the interpretation of the darkening wave in RS CVn systems as arising from plage regions analogous to the sun's (Hall 1976). Quasi-stationary loops of X-ray emitting plasma may also explain the temporal behavior of RS CVn binaries (Holt et al. 1979; Walter et al. 1980). Walter et al. developed and discussed applications of a quantitative coronal model using the scaling relation between loop length, temperature and gas pressure derived by Rosner, Tucker and Vaiana (1978) (hereafter referred to as RTV). Magnetic loops provide scenarios for a number of optical and UV results for rapidly rotating stars (Linsky 1980a and references therein) and a basis for understanding X-ray emission from most stars, at least those of spectral type A and later (Rosner and Vaiana 1980; Linsky 1980b).

The Solid State Spectrometer (SSS) on the Einstein Observatory (Joyce et al. 1978), confirmed thermal line emission from Capella with the identification of Mg, Si, S, and Fe features (Holt et al. 1979). It also showed that the gas was not isothermal. Most of the emission was consistent with $\sim 5 \times 10^6$ K, but about a tenth of the luminosity was at higher energy and could be explained by a 5×10^7 K gas.

Analyses of data from observations with the SSS of 6 other RS CVn systems, and from another observation of Capella, have now been carried out. Our sample of RS CVn stars includes σ Cor B, AR Lac, HR1099, RS CVn, UX Ari

and λ And, with periods 1.1 - 20.5d. Swank and White (1980) gave a preliminary report and discussed fits of the SSS spectral data with combinations of collisional ionization equilibrium models calculated by Raymond and Smith (1977, 1979). In this paper we summarize the results and discuss the significance of our multi-temperature models of X-ray emission from these stars. Agrawal, Riegler and White (1980) have given a detailed account of the observation of σ Cor B. More complete descriptions of the other obserevations will be given in a subsequent paper (White et al. 1980b). White et al. (1980a) found that the X-ray spectrum of Algol is similar to those of the RS CVn systems and suggested that the cooler star in this system also has an active corona. Therefore it is of interest to consider Algol in the same way and we have added it to the sample we discuss here.

II. SPECTRAL RESULTS

The coronal emission of these stars is likely to be the superposition of contributions from optically thin gas over a range of temperatures, with near equilibrium between radiation and heating in the absence of fast flaring. We have approximated departures from isothermality with allowance for as many as five separate isothermal components. The ionization balance and the emission of each important element are calculated separately in the Raymond-Smith models. The abundances of Mg, Si, S, and Fe were allowed to vary from solar. The best fit abundances (given in Swank and White (1980)) were within a factor two of solar, and in most cases solar abundances were within the 90% errors. Density dependence is not important for the high Z elements which are responsible for the line contributions above .5 keV.

In each case the fit to two temperature components was markedly better than the fit to an isothermal model. The average values of χ^2 were 73 and 221 for 58 and 60 degrees of freedom, respectively. The ratio of luminosities of the high to the low temperature components ranged from 0.1 for Capella to 4.0

for an observation of UX Ari. Figure 1 displays the raw data and the best fits for these two extremes in our sample. The 160 eV detector resolution can be gauged from the response in the Capella spectrum to the Helium-like Si triplet at ~ 1.85 keV. Below 1.5 keV, although the individual contributions may not be resolved, most of the flux is due to line emission, especially by Fe. The peak near 1 keV in the spectrum of UX Ari is due to a prominent FeXX transition and is resolved with the SSS. Fe lines could be identified in the UX Ari proportional counter spectrum obtained by Walter, Charles and Bowyer (1978), and those authors could determine only an average temperature. The energy resolution and the dynamic range of the SSS together make possible the identification of two temperatures. Several RS CVn sources could also be seen from 2 keV to about 15 keV with the HEAO A2 medium and high energy detectors (Swank et al. 1980) and these observations confirm the high temperature flux. The sources were too weak, however, for that experiment to distinguish the presence of Fe Kα line emission.

Introduction of additional components at temperatures other than those giving the best two component fits did not significantly improve the fits and only relatively small amounts of gas at intermediate temperatures were acceptable. The distribution may well be more complex than two isothermal components, but it is interesting to examine the implications of this approximation.

Figure 2 shows the emission measures (EM) and temperatures of the separate components. Table 1 gives the values and the distances used in computing the emission measures, along with the corresponding luminosities. Multiple values are given if we observed changes in the source. The .5 - 4 keV range of the SSS includes several prominant lines which are very sensitive to the temperature in the range 1-20 x 10^6 K. These determine the low temperatures rather precisely. For the higher temperatures the line emission is not prominant for near solar abundances and these temperatures are less

accurately determined. Systematic errors due to uncertainties in the atomic physics of the models are not expected to greatly affect determinations based on so broad a spectral band for the energies and temperatures of interest (Raymond and Smith 1977; Raymond 1980).

For the low temperature component both the temperatures and emission measures are very similar for the entire set. For the short period sources AR Lac, Algol and UX Ari we observed two or three flux and spectrum states, but the low temperature contributions were indistinguishable. Only for Capella did the low temperature component change significantly. The dispersion of emission measure and temperature for the high temperature component is significantly larger than for the low temperature one. All of the variations in the shorter period sources could be associated with the high temperature component alone.

We have assumed that two separate plasmas exist, each approximately in collisional ionization equilibrium. The fluxes we observed were constant over hours. We estimate, following Kafatos and Tucker (1972), that most ionization states would have reached equilibrium, although high Z ions could take hours to equilibrate in an extended hot component if the density is as low as $\sim 10^8$ cm^{-3}. The independent variability of the high and low temperature components in the two temperature model also argues for this interpretation. Non-equilibrium conditions could obtain, despite constant flux, for steady state flow in a temperature gradient (Raymond and Dupree 1978). That there are a few abundances which can differ by as much as a factor of two from solar (high for Capella, low for HR1099, UX Ari and λ And) may indicate that the ionization temperature and kinetic temperature are not the same, rather than any abundance anomaly. However, that they are usually so close to solar seems to confirm the validity of the approximation.

III. EMISSION REGIONS

The RS CVn binaries in our sample include a G or K subgiant and an F or G

dwarf or subgiant (see Table 2), while Algol contains a K subgiant with a B main sequence star. The low temperature luminosities we found were in the range 10^{30} - 10^{31} ergs s^{-1} and the high temperature luminosities were in the range 2×10^{29} - 2×10^{31} ergs s^{-1}. From the Einstein Observatory Imaging Proportional Counter results (Vaiana et al. 1980), F and G dwarfs could have X-ray luminosities $\sim 10^{30}$ ergs s^{-1} and contribute some of the X-ray emission in the RS CVn systems, although it has been assumed (e.g. Walter et al. 1980) that the star which is the dominant source of the chromospheric indicators of the sort seen in solar plage regions (usually the later type star) is the dominant X-ray source. However, if rotation leads to enhanced X-ray emission from Capella Ab (Ayres and Linsky 1980), it could affect both stars in the synchronous binaries. In the following we consider the consequences of assuming that each X-ray component is associated with one or both of the stars in the binary or in the region between them. Although the two temperature components could be physically interdependent, they imply separate emission regions and we will apply the ideas for estimating their dimensions to them separately.

With the approximation that the density is uniform in a volume V extending above the star a height ℓ over a solid angle $2\pi f$, the observed emission measure 10^{53} $EM_{53} = n_e^2 V$ implies

$$\frac{\ell}{R} + \left(\frac{\ell}{R}\right)^2 + \frac{1}{3}\left(\frac{\ell}{R}\right)^3 = 360\ EM_{53}\ T_7^2\ P^{-2} R^{-3} f^{-1}, \qquad (1)$$

where R is the stellar radius in units of the solar radius, p is the pressure and $T_7 = T/10^7$ K. If $\frac{\ell}{R} \gg 1$, we could see at least parts of some regions extending above the back hemisphere and f could approach 2. If $\ell/R \ll 1$, $f < 1$. The pressure has been assumed to be similar to average pressures detected at the top of the chromosphere or in the transition region (Walter et al. 1980; Ayres and Linsky 1980; Simon, Linsky and Schiffer

1980). Simon and Linsky (1980) found that several pressure indicators agreed on the range 0.2 - 1 dynes cm^{-2} for UX Ari and HR 1099. Simon, Linsky and Schiffer (1980) estimated factor of two enhancement in a flare of UX Ari. On the other hand, measurements of X-ray emission associated with loops on the sun imply a range of pressures up to 100 dynes cm^{-2} (e.g. Pallavicini et al. 1977; Feldman and Doschek 1978). A similar magnetic structure of the stellar coronae, with $f < 1$, would allow loop pressures significantly higher than the average values given by transition region line ratios.

Figure 3 shows ℓ/R obtained for both temperature components assuming the source is the active star. The points are plotted for $f = 1$ and a pressure of 3 dynes cm^{-2} with the "error" bars showing the range for $p = 1$-10 dynes cm^{-2} (the lower pressures corresponding to the larger emission regions). Uncertainties for a given pressure are less than this range. If the emission were associated with the other star the extent above the surface would be about the same or larger. Dividing the emission between them would lower all of the values, by up to a factor of 2 for low values but only by $\sqrt[3]{2}$ for large ones.

In Figure 3 the values for the high temperature component all lie above those for the low temperature component, which are on the order of or smaller than the stellar radii. Algol is not distinguishable by emission region sizes from the shorter period RS CVn binaries. For the range of pressures plotted the shorter period binaries all have a high temperature component which can be associated with a source the size of the binary separation. Except for λ And and Capella, pressures of 20-30 dynes cm^{-2} would be required for the gas to be confined to within a stellar radius.

If we suppose that the volume is actually in the form of ropes of gas confined by magnetic fields and apply the RTV scaling relation.

$$\frac{L}{R} = 5\ T_7^{\ 3}\ p^{-1}\ R^{-1}, \qquad (2)$$

where L and R are in units of solar radii, the high temperatures imply loop heights L large compared to the radii for pressures in the same range discussed above. The relation was derived for lengths less than the pressure scale height (and < R), so that numerical application of the equation is not justified in this case; however, it does corroborate the implication that unless the pressures are very large the loops would have to be very large. According to equation (2) loops less than a scale height are possible for high enough pressures, > 100 dynes cm^{-2} for the high temperatures and > 10 dynes cm^{-2} for the low temperatures. Then the approximation should be reasonable and for a given f we can require, as did Walter et al. (1980), equality between loop height (L) and extent of the emission region (ℓ).

Walter et al. (1980) absorbed the non-linearity of the left side of equation (1) into an effective f, which could be >>1, and chose it to give the pressure indicated by optical and UV measurements. Instead, we assume that different pressures are possible and ask what we can conclude about the two components. For the low temperatures the curves of ℓ/R and L/R as functions of p cross for f = 1. Table 2 shows the resulting values of p and L/R. The loops are small relative to the stellar radii, but pressures exceeding 10 dynes cm^{-2} are required. The solutions for p increase for f < 1, so these are the minimum consistent values. With pressures as high as 10 dynes cm^{-2} covering the stellar surface, the lower average transition region pressures are difficult to understand, so that, if the emission is from small loops for which the RTV scaling applies, f < 1 and even higher pressure, seem more likely. High temperature solutions are only possible if f << 1. For these Table 2 shows the values of f and L/R for pressures of 100 dynes cm^{-2} (which are observed in solar flares). The fractions of the stars covered would be on

the order of the fraction of the sun covered with active regions (Vaiana and Rosner 1978). For the short period binaries the loops would still be on the order of the stellar radii.

IV. DISCUSSION

The low temperatures (4-8 x 10^6 K) are in the range observed for solar flares, somewhat higher than in typical active region loops (Vaiana and Rosner 1978). While the stars can be viewed as covered by active regions similar to those on the sun, the pressures and characteristic sizes allowed are not typical of the sun. Either the loops are larger or the pressures higher. The high temperatures (> 20 x 10^6 K) occur in solar flares, but these stars differ from the sun in having similar quasistatic high and low temperature emission measures.

The spectral data alone cannot decide between confinement at high pressure and large extent at relatively low pressures. Walter, Charles and Bowyer (1978) pointed out that a confined geometry would imply a number of temporal correlations; for example, coronal loops extending only a fraction of a stellar radius above the photosphere would be subject to occultations. The SSS observed binary phase intervals of .1 about primary and secondary eclipses for AR Lac without seeing any significant change during either transit and no difference (within errors of 30%) between the soft components during the two observations (Swank and White 1980). While the lack of change during transit is not very restrictive, the near equality of the low temperature components implies this component is not small compared to the stellar radii or that both stars contribute on the same order (White et al. 1980b). The high temperature component was smaller during occultation of the K star, although no time dependence interpretable as occultation of a very small region was observed. Similar changes in UX Ari and RS CVn could have been due to such regions rotating in or out of view. But, alternatively, the emission measure could have changed between observations. Only for Algol was the time scale of

change observed ($\sim 12^h$) and the light curve indicated a flare of the hard component (White et al. 1980a). Thus neither previous observations, nor our new temporal data, resolve the scale sizes of the emission and determine the way in which these coronae differ in structure from that of the Sun.

Walter et al. (1980) argue that if the corona is made up of loops, the variability observed may be related to the number of loops. They assumed the loops to be cylinders of radius proportional to their height L, i.e. of volume $2\pi\alpha^2 L^3$, with N of them filling the emission volume V. In terms of our parameters,

$$N\alpha^2 = f\left[\frac{1}{(L/R)^2} + \frac{1}{(L/R)} + \frac{1}{3}\right]. \tag{3}$$

Our observations are consistent with a connection between the number of loops and variability: $N\alpha^2$ is large for the low temperature solutions of relatively high pressures and small L/R shown in Table 2 and small for the high temperature components. While we cannot conclude from a small value of $N\alpha^2$ that we should observe variability, since large N can still be accommodated if $\alpha \sim .1$ (Golub et al. 1980) and single loops could be very extended, this picture would allow the occasional high temperature changes we observed.

It has been pointed out already by Simon and Linsky (1980) that for the transition region pressures they measured and the temperature reported by Walter, Charles and Bowyer for UX Ari (10^7 K) the RTV loop scaling relation gives loops as large as the binary separation. Simon, Linsky, and Schiffer (1980) found evidence for Doppler shifts suggesting material falling on the primary, perhaps transferred along field lines connecting the two stars. The observation coincided with a large radio flare and they suggested that reconnection of field lines provided the radio flare energy source, and could have given rise to an X-ray flare as well.

Out of our sample of 8 sources all but Capella and RS CVn (the latter the most distant of the sample) are radio binaries (Owen and Gibson 1978; Spangler, Owen and Hulse 1977), in which the emission is thought to be due to relativistic electrons in fields of 10-100 g (e.g. Owen, Jones and Gibson 1976; Feldman et al. 1978). The radio source sizes appear to be on the order of the binary orbits (e.g. Clark et al. 1976; Owen and Spangler 1977). Evidence for free-free absorption in the radio spectra suggests gas in the same region, which could be contributing at least part of the X-ray emission (Gibson, Hicks and Owen 1978). Thus consistency appears possible between the radio and X-ray pictures, with the emission region of at least one component being as extended as the radio source. Either of the components we observed could produce cutoffs in the GHz range. A few observations have implied correlation between radio and X-ray flares (White, Sanford and Weiler 1978; Newell et al. 1979), that is, between the acceleration of electrons and the supply of hot gas. This suggests that the high temperature luminosity will be correlated with average radio luminosity. The upper limits for radio flux from Capella, in comparison with the detection of λ And are consistent with such a correlation.

As noted above, the high temperature components for Capella and λ And are not required, for moderate pressure and $f \sim 1$, to be extensive compared to the stars (although for $f \ll 1$ they could be). Furthermore, they have the lowest average surface fluxes at both temperatures. Since they are the slowest rotators of our sample, this may be an example of correlation of rotation with generation of fields, with other factors associated with the stars themselves responsible for the difference between λ And and Capella. On the other hand the stars in these wider binaries should interact less and interaction may in some way amplify the production of higher temperature plasma.

V. SUMMARY

Two results of these observations stand out. All of the systems in the sample contain, in terms of collisional equilibrium models, (1) coronae in the narrow temperature range 4-8 x 10^6 K and (2) gas an order of magnitude hotter, at 20-100 x 10^6 K.

The salient characteristics of the low temperature component are:

a. The emission measures are all a few x 10^{53} cm^3.

b. No significant change in emission measure was observed for any source.

c. The abundances of Mg, Si, S, and Fe are within a factor of two of solar, relative to lower Z elements.

d. The emission regions are stellar-sized if the pressures are 1-10 dynes cm^{-2} and could be confined to magnetic loops covering the stars. In that case occultations may not be noticeable. This component could for pressures < 1 dyne cm^{-2} be extended enough to interact with a close companion.

For the high temperature component:

a. The emission measures range from 2 x 10^{52} cm^3 to 3 x 10^{54} cm^3.

b. Factor of two changes in emission measure occurred in three sources.

c. Except for Capella the emission regions extend as far as the binary companion, if the pressures are no higher than 10 dynes cm^{-2}. But if the pressures exceed 100 dynes cm^{-2}, this component could be confined to small spots on the stellar surfaces. In the latter case, occultations of the high temperature component should occur, and such high temperature components should be found for single rotating stars.

If either component extends to the companion in the close binaries, part of the X-ray emission may be a binary interaction and would not be observed for single stars. The radio and X-ray properties of this sample suggest such an interaction. For such an extended component only partial occultations and little dependence on photometric wave phase would be expected, but there could

still be correlation with star spot cycles and possibly with orientation of the spots with respect to the companion.

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TABLE 1. X-RAY PROPERTIES$^+$

SOURCE	d(pc)	T_1	log EM_1	T_2	log EM_2	$\mathcal{L}_1$	$\mathcal{L}_2$
σ Cor B	23	5.8 ± 0.6	$53.3^{+0.1}_{-0.4}$	46 ± 12	52.9 ± 0.1	25 ± 1.6	0.7 ± 0.1
AR Lac	50	6.7 ± 0.7	53.51 ± 0.15	93 ± 35	53.5 ± 0.1	4.5 ± 0.7	3.0 ± 0.5
		7.4 ± 0.7	53.53 ± 0.15	43 ± 7	53.9 ± 0.1	4.5 ± 0.7	7.0 ± 1.0
HR1099	35	6.7 ± 0.5	53.4 ± 0.3	48 ± 9	53.75 ± 0.06	$3.5^{+3}_{-0.8}$	4.4 ± 0.9
Algol	30	8.2 ± 0.9	$53.1^{+0.2}_{-0.4}$	33 ± 13	53.51 ± 0.06	1.1 ± 0.2	2.1 ± 0.4
		7.0 ± 0.6	53.0 ± 0.2	48 ± 16	53.87 ± 0.06	2.1 ± 0.3	6.8 ± 0.7
RS CVn	145	7.0 ± 1.2	53.4 ± 0.2	96 ± 35	54.0 ± 0.1	4.0 ± 0.8	9.0 ± 1.0
UX Ari	50	7.8 ± 0.6	53.8 ± 0.1	46 ± 5	54.0 ± 0.1	5.7 ± 0.6	8.5 ± 0.9
		7.9 ± 0.6	53.8 ± 0.2	31 ± 4	54.2 ± 0.1	7.3 ± 0.7	13.4 ± 1.0
		7.5 ± 0.4	53.7 ± 0.2	65 ± 10	54.5 ± 0.1	6.8 ± 0.7	19.7 ± 2.0
λ And	26	6.8 ± 0.3	53.3 ± 0.1	36 ± 12	53.3 ± 0.1	2.5 ± 0.7	1.6 ± 0.6
Capella	14	6.0 ± 0.3	$52.9^{+0.3}_{-0.8}$	30^{+40}_{-10}	$52.3^{+0.1}_{-0.2}$	1.9 ± 0.9	0.24 ± 0.05
		4.0 ± 0.2	$53.4^{+0.4}_{-0.2}$	26 ± 15	52.3 ± 0.1	3.0 ± 0.2	0.3 ± 0.1

^+T_i in 10^6 K, $EM_i = \int n_e^2\, dV$ in cm^{-3}, $\mathcal{L}_i$ in 10^{30} ergs s^{-1} for .4 - 4 keV.

For the low temperatures (i=1), ∼ 90% of the luminosity is included. For the high temperatures (i=2), the luminosity above 4 keV could approach 50% of the values given. The flux was assumed isotropic in computing the luminosity. Errors include 90% confidence statistical errors allowing variable abundances of elements (Swank and White 1980). In some cases the errors are larger to include fits in which the model abundance of Fe is solar.

TABLE 2. SYSTEM PARAMETERS+ AND LOOP SOLUTIONS

SOURCE	P(d)	Sp	$R(R_0)$	$a(R_0)$	Low T Loops p	Low T Loops L/R	High T Loops f	High T Loops L/R
σ Cor B	1.14	?	2	6	56	.1	.05	2.5
		F6V	1.3					
AR Lac	2.0	KOIV	3.1	9	33	.02	.0004	1 3
		G2IV	1.8				-.05	-1.3
HR1099	2.8	K1IV	2.8	11	30	.02	.02	1.9
		G5IV	3.0					
Algol	2.9	K IV	3.4	14	9	.1	.025	1.7
		B8V	3.0				-.035	-.6
RS CVn	4.8	KOIV	4.0	17	14	.03	.0008	11
		F4V	1.7					
UX Ari	6.4	KOIV	3.1	20	50	.02	.03	5
		G5V	1.0				-.2	-.5
λ And	20.5	G8III-IV	6.2	45	5	.06	.007	.4
	(50)	?	3.0					
Capella	104	F9III	7.1	160	1-10	.01-1	.0009	.2
	(12)	G6III	11.6					

Col 2: Binary period in days. Values in parenthesis are rotation periods.

Col 3,4: Spectral types and radii of most active star and its companion.

Col 5: Semi-major axis of binary.

Col 6,7: For the low temperature component pressure, p, in dynes cm^{-2} and ratio of loop height to active star radius, L/R, consistent with T and EM, if f = 1.

Col 8,9: For the high temperature component f and L/R consistent with T and EM, if p = 100 dynes cm^{-2}. Ranges are for the set obtained for multiple observations.

+For references see Swank and White (1980).

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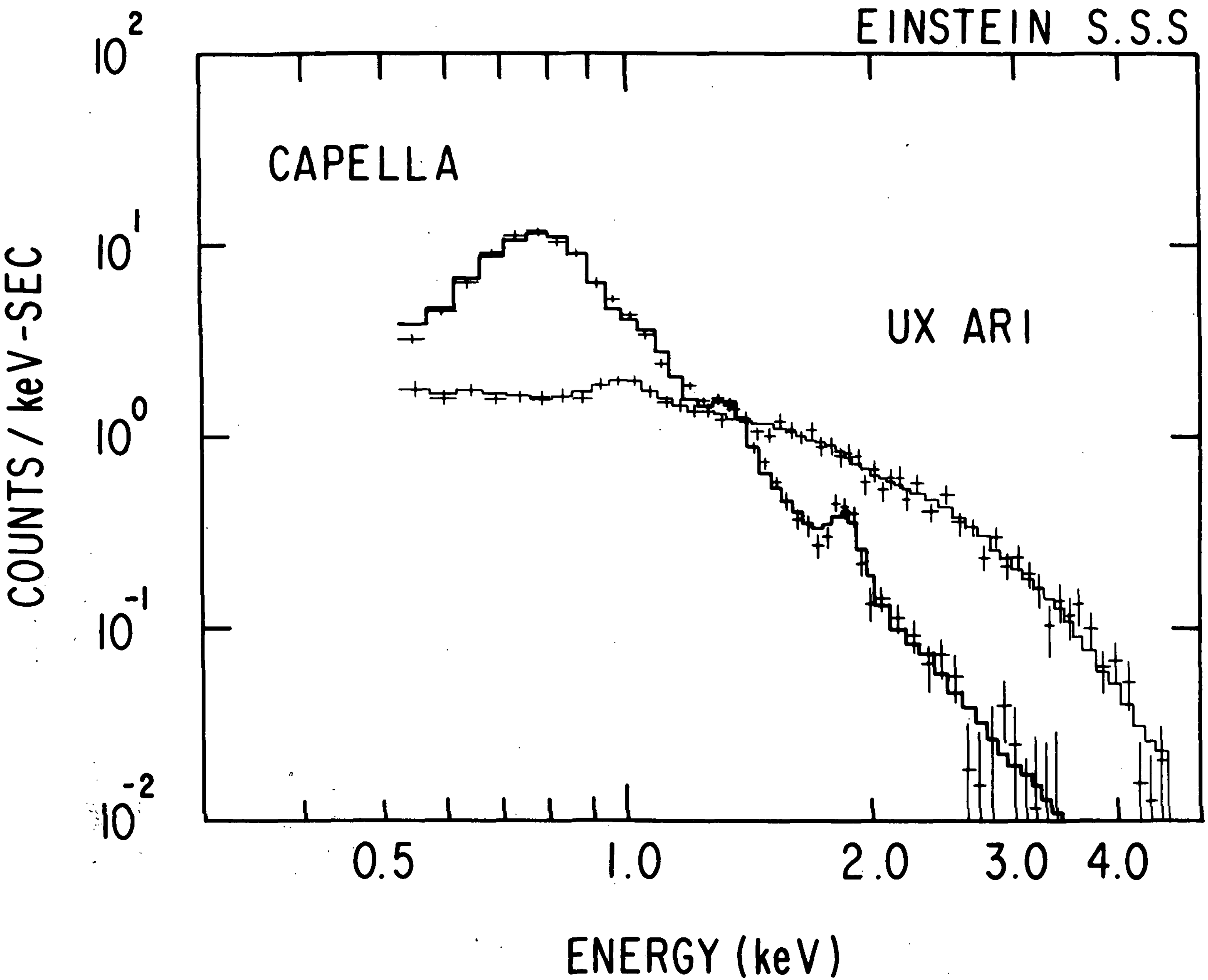
FIGURE CAPTIONS

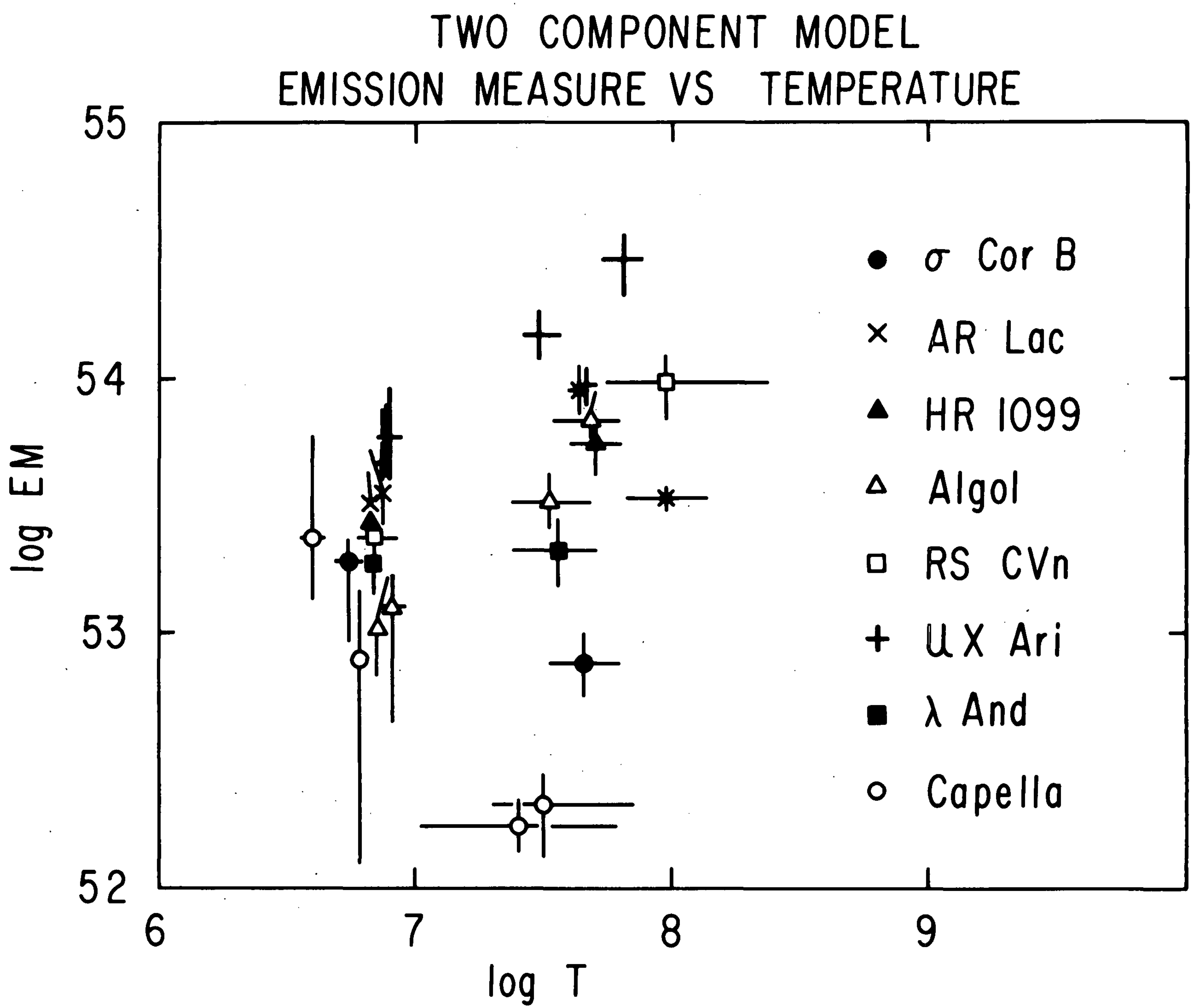
Figure 1 - Pulse height spectra of Capella on Sept. 17, 1979 (6 mo. after the observation reported by Holt et al. (1979)) and UX Ari on Aug. 11, 1979. The histograms show the Solid State Spectrometer response to the best fit models.

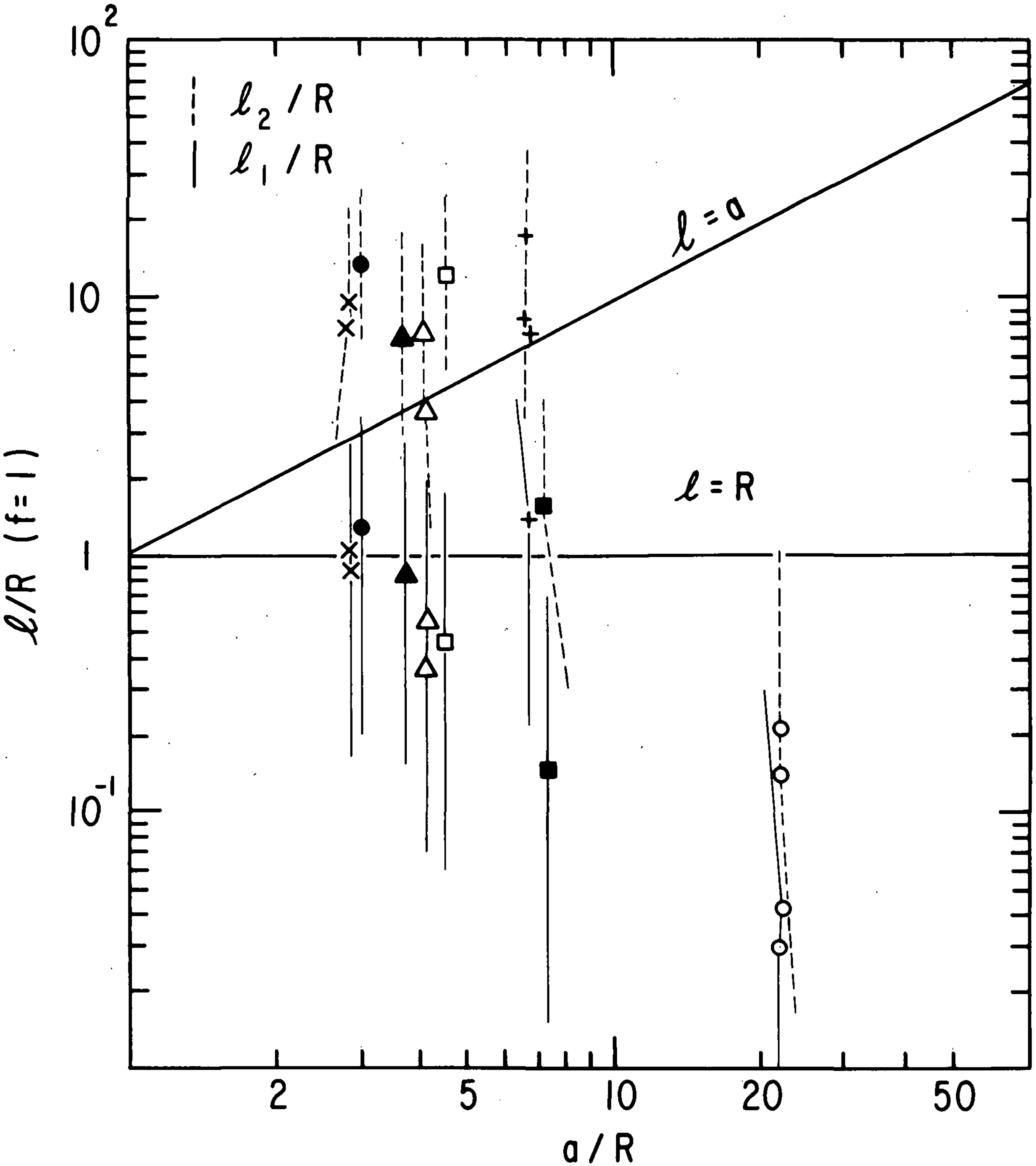
Figure 2 - Emission measures and temperatures of the two components. Separate points are plotted for each flux level observed. All of the points for the low (high) temperature components are to the left (right) of log T = 7.

Figure 3 - Extents above the active stars of emission regions of the two components when a hemisphere is covered (f = 1). Symbols corresponding to the sources as in Figure 2 are plotted for p=3 dynes cm^{-2}. The bars (solid for low temperature component, dashed for high temperature) show the range allowed by p = 1-10 dynes cm^{-2}.



EINSTEIN S.S.S
CAPELLA
UX ARI
COUNTS / keV-SEC
10^2
10^1
10^0
10^{-1}
10^{-2}
0.5
1.0
2.0
3.0
4.0
ENERGY (keV)


TWO COMPONENT MODEL
EMISSION MEASURE VS TEMPERATURE
log EM
log T
55
54
53
52
6
7
8
9
σ Cor B
AR Lac
HR 1099
Algol
RS CVn
UX Ari
λ And
Capella



ℓ_2 / R
ℓ_1 / R
$\ell = a$
$\ell = R$
ℓ/R (f=1)
a / R
10^2
10
1
10^{-1}
2
5
10
20
50

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16. Abstract

A summary is presented of results from the Solid State Spectrometer on the Einstein Observatory for 7 RS CVn binaries. The spectra of all require two emission components, evidenced by line emission characteristic of plasma at 4-8 x 10^6K and bremsstrahlung characteristic of 20-100 x 10^6K. We interpret the data in terms of magnetic coronal loops similar to those seen on the sun, although with different characteristic parameters. The emission regions could be defined by separate magnetic structures. For pressures less than $\sim$ 10 dynes cm^{-2} the low temperature plasma would be confined within the stellar radii, while the high temperature plasma would, for the synchronous, close binaries, fill the binary orbits. However, for loop pressures exceeding 100 dynes cm^{-2}, the high temperature components would also be confined to within the stellar radii, in loops covering only small fractions of the stellar surfaces. While the radio properties and the occurrence of X-ray flares suggest the larger emission regions, our observations of time variations leave the ambiguity unresolved.

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